AD-A061 759 ROYAL AIRCRAFT ESTABLISHMENT FARNBOROUGH (ENGLAND) F/G 11/6
STRESS CORROSION TESTING OF AU4SG ALUMINUM ALLOY IN PLATE FORM.(U)
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ROYAL AIRCRAFT ESTABLISHMENT

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Technical Report 78054

May 1978

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by

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(18) DRIC (19) BR-64627

UDC 669.715-413 : 620.194.2

(14) RAE-TR-78054

ROYAL AIRCRAFT ESTABLISHMENT

(9) Technical Report 78054

Received for printing 19 May 1978

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SUMMARY

The resistance to stress corrosion cracking in the short transverse direction of the aluminium alloy AU4SG (2014 type plate) was assessed after ageing to peak strength, at either 160°C or 175°C, and after overageing at these two temperatures. The resistance to stress corrosion cracking was measured using constant strain tensile tests with alternate immersion in aqueous 3.5% NaCl, and by exposure to a marine atmosphere. Constant strain rate tests in 1 M aqueous NaCl, both freely corroding and anodically polarized, were also used.

AU4SG, aged to peak strength was very susceptible to stress corrosion cracking, cracks occurring in the alloy stressed in the short transverse direction at less than 30 MPa. Overageing, to produce a 10% reduction in 0.2% proof stress improved the resistance to stress corrosion cracking, although cracking occurred at short transverse stresses below 60 MPa. Stretching the alloy after solution treatment accelerated the ageing process but did not improve the resistance of the alloy to stress corrosion cracking at given strength levels. Ageing at 160°C did not result in any significant improvement in stress corrosion cracking resistance compared with ageing at 175°C. Tests on 2014 type alloy, produced to DTD 5020A, indicated that this alloy was more resistant to stress corrosion cracking than the overaged AU4SG tested.

Departmental Reference: Mat 350

(11) May 78 (12) 25p.

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1 INTRODUCTION

As part of a collaborative programme with members of GARTEur 3* it was agreed that Materials Department, RAE, should carry out stress corrosion tests on AU4SG aluminium alloy supplied by ONERA**, Chatillon, Paris, so that the test methods used by the two laboratories could be compared.

Work at ONERA[1] had shown that, after solution treatment at 510°C for 6 to 24 hours, peak hardness was achieved by ageing for either 20 hours at 160°C, or 8 hours at 175°C. Stress corrosion tests were done on material aged to peak hardness and on the alloy underaged and overaged to produce a 10% reduction in the 0.2% proof stress (PS). The alloy was tested both under constant load and at low strain rates, using short transverse test pieces. Freely corroding conditions were used in alternate immersion tests, but in total immersion tests some test pieces were anodically polarized.

Two corrosive media were used:

(a) a solution containing 3% NaCl buffered with disodium phosphate and boric acid, with the pH adjusted to 8 with sodium carbonate (solution A3 of French Air Standard 0754/A);

(b) a solution of 3% NaCl plus 0.2% potassium dichromate; this solution had a pH of 4.

In the alternate immersion tests, test pieces were placed in individual closed cells which were filled and emptied so that the specimens were immersed for 10 minutes and un-immersed for 50 minutes. Under these conditions the test piece was in a confined high humidity atmosphere while un-immersed, in contrast to the alternate immersion test conditions specified in ASTM G44-75 [2] which requires the test piece to dry during the un-immersed period.

The ONERA tests showed that AU4SG, underaged or aged to peak hardness, has poor resistance to stress corrosion cracking. Overageing, particularly at the lower of the ageing temperatures, markedly increased resistance to stress corrosion cracking at the cost of a 10% reduction in 0.2% PS.

Aluminium plate alloy of the 2014 type, produced to DTD 5020A specification[3], had previously been tested at RAE[4,5]. This material, however, was

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* GARTEur - Group for Aeronautical Research and Technology in Europe - 3, subgroup dealing with research on airframe materials.

** ONERA - Office National d'Études et de Reserches Aérospaciales. (France)

stretched to give a permanent deformation of 2.5% between solution treatment and ageing, whereas the AU4SG tested by ONERA was not stretched after quenching.

This Report describes the results of RAE stress corrosion tests on AU4SG heat treated to peak hardness and overaged in the manner described previously[1]; and, so that comparison could be made with alloy produced to DTD 5020A, on AU4SG which had been stretched.

2 MATERIAL AND TEST PIECES

2.1 Material

62mm thick as-rolled AU4SG plate was supplied by ONERA. The chemical analysis of the material is given in Table 1. The figures for Mn and Fe are slightly lower than those quoted by ONERA[1]. Nominal compositions for 2014 and DTD 5020A and the actual analysis of the DTD 5020A used previously[4,6] are also given.

2.1.1 Unstretched material

Four blocks of AU4SG, each approximately 100 × 38 mm, were solution treated, quenched and then aged as shown in Table 2.

2.1.2 Stretched material

Five blocks of AU4SG, each approximately 195 (L) × 13 mm, were solution treated, quenched then stretched in the longitudinal (L) direction to give a permanent deformation, measured over the central section, of 2.2 to 2.6%. The alloy was then aged at 160°C for the times listed in Table 2. The lower ageing temperature (160°C) was used because previous work[1,7] had indicated that alloy overaged at that temperature was more resistant to stress corrosion cracking than alloy overaged at 175°C. All heat treatments were carried out in air-circulating ovens.

2.2 Test pieces

All test pieces were cut so that the stress was applied in the short transverse direction. Tensile properties were determined on 3.99mm diameter test pieces conforming to BS4A4. For the stress corrosion tests, 3.175mm diameter test pieces of the type specified in G47-76[8] were used (see Fig 1).

Test pieces for preliminary tests on the stretched material were produced from that part of the blocks outside the centre section but not affected by the grips of the tensile machine. Fig 2 shows a cutting diagram for these blocks.

3 MECHANICAL PROPERTIES

The tensile properties of unstretched and stretched AU4SG are given in Table 3. The properties of the unstretched alloy are within ±3% of those obtained by ONERA[1].

The 0.2% proof stress and tensile strength of quenched and stretched AU4SG, as a function of ageing time at 160°C, are shown in Fig 3. The properties for unstretched alloy aged for 20 and 240 hours are also shown. Overageing is accelerated by stretching and an approximate 10% strength reduction is achieved in half or less than half the time required for the unstretched alloy. It would appear to be valid, therefore, to compare the stress corrosion properties of alloy aged 72 hours after stretching with unstretched alloy aged for 240 hours.

4 CONSTANT STRAIN RATE STRESS CORROSION TESTS ON UNSTRETCHED MATERIAL

Test pieces were pre-loaded to 0.5 kN in a Mayes 20 kN constant strain rate machine. A cell was fitted around the test piece into which corrodent was circulated. The corrodent was aerated 1 M NaCl solution at 30°C. Test pieces were tested at a strain rate of approximately $4.3 \times 10^{-6}\ s^{-1}$:

(a) in freely corroding conditions;

(b) with poteniostatic control at 50 and 100 mV anodic to E_R , and

(c) with galvanostatic control at anodic currents of 10, 30 and 60 mA.

Full details of these tests have been reported separately[6].

These tests showed[6] that AU4SG was more resistant to stress corrosion cracking in chloride solutions when overaged than when aged to peak strength. The results did not indicate whether there was any advantage to be gained in overageing the alloy at 160 or 175°C: when freely corroding, material aged at 175°C appears more resistant; when under galvanostatic anodic polarization material aged at 160°C appears to be more resistant; and when under potentiostatic anodic polarization there is no apparent difference in stress corrosion resistance between material aged at the two temperatures.

5 CONSTANT STRAIN STRESS CORROSION TESTS

The test pieces were strained in the RAE one-piece test rigs (see Figs 4 and 5), a modification of the Alcoa test frame. Strain was measured on each test piece by a 10mm gauge length clip gauge. Before exposure to the corrosive environment the frames were protected with a water-white, hot dip, strippable

coating conforming to PX-15. Full details of the test rig and its use are contained in Ref 4.

5.1 Environments

Constant strain tests were exposed to two environments:

(a) a natural marine atmosphere at the CDL Exposure Trials Station at Eastney, approximately 100 m from high water mark. The straining rigs and test pieces were supported on racks at 45^{o} to the horizontal, facing south, and were exposed for 18 months (or less if failure occurred) between September 1975 and April 1977. This included the unusually dry period of 1976;

(b) alternate immersion in 3.5% NaCl solution at 30^{o}C for 30 days[2], or less if failure had occurred. These conditions differ slightly from those given in G44-75 in that the solution was kept at $30^{o} \pm 1^{o}$C and the temperature and humidity of the laboratory air was not accurately controlled. Over a period of months, the air temperature varied between 23 and 26^{o}C, and the humidity between 35 and 60% RH. The rate of evaporation of water from a 12cm diameter dish placed adjacent to the tanks varied between 0.16 and 0.21 g $cm^{-2}\ d^{-1}$. The test pieces dried after being un-immersed for 20 to 30 minutes. G44-75 specifies room and solution temperature controlled to $\pm 1^{o}$C and suggests an arbitrary temperature of 27 ± 1^{o}C. Humidity should be controlled at 45 ±6% RH, and test pieces should dry within 40 minutes.

5.2 Microscopic examination of test pieces

Constant strain test pieces unbroken at the conclusion of exposure were sectioned to show a central L/ST plane, polished, and examined microscopically for evidence of stress corrosion cracking. The guide lines used to determine whether stress corrosion cracking had occurred are similar to those used by Sprowls *et al*[9] and specified in G47-76[8], *viz*:

(1) cracks that followed an intergranular path or mixed intergranular-transgranular path were considered to be stress corrosion cracks;

(2) exclusively transgranular cracks that initiated in corrosion pits were not considered to be stress corrosion cracks;

(3) intergranular fissures that were no deeper than localised areas of intergranular corrosion were not considered to be stress corrosion cracks.

Figs 6 and 7 show examples of stress corrosion cracks and intergranular corrosion, respectively.

5.3 Constant strain stress corrosion tests on unstretched material

Tables 4 and 5 show results of tests in alternate immersion and marine atmosphere environments for unstretched material.

In this Report, in accordance with usual UK and US practice, threshold stress is defined as *that stress at and below which failure is not detected.* This can be judged by *macro-failure* - stress corrosion cracks detected by examination of the test piece surface at up to ×10 magnification, or by *micro-failure* - stress corrosion cracks detected by microscopic examination (at up to ×500 magnification) of a polished L/ST section.

The macro-failure threshold stresses obtained from alternate immersion testing in 3.5% NaCl, expressed also as a percentage of the relevant 0.2% PS, were:

aged 20 hours at 160°C 62 MPa (13.75%);
aged 8 hours at 175°C 89 MPa (21.25%);
aged 240 hours at 160°C >244 MPa (>55%);
aged 48 hours at 175°C 91 MPa (22.5%).

Whereas after marine exposure, macro-failure thresholds were:

aged 20 hours at 160°C <22 MPa (<5%);
aged 8 hours at 175°C 44 MPa (10%);
aged 240 hours at 160°C 88 MPa (22.5%);
aged 48 hours at 175°C >91 MPa (>22.5%).

Judged by micro-failure criteria, threshold stresses after alternate immersion and marine atmosphere exposure were, respectively:

aged 20 hours at 160°C 22 MPa (5%) and <22 MPa (<5%);
aged 8 hours at 175°C 22 MPa (5%) and <22 MPa (<5%);
aged 240 hours at 160°C 50 MPa (12.5%) and <60 MPa (<15%);
aged 48 hours at 175°C 50 MPa (12.5%) and <50 MPa (<12.5%).

5.4 Constant strain stress corrosion tests on stretched material

Preliminary stress corrosion tests were made on test pieces machined from material outside the central section of each block, adjacent to the grip marks (see Fig 2). These tests, on material aged at 160°C, indicated micro-failure threshold values of approximately:

aged 12 hours, 45 MPa (10% of 0.2% PS);
aged 20 hours, 42 MPa (10% of 0.2% PS);
aged 72 hours, 50 MPa (12.5% of 0.2% PS);
aged 144 hours, 80 MPa (20% of 0.2% PS);
aged 240 hours, 110 MPa (30% of 0.2% PS).

The results obtained influenced the stress levels at which stress corrosion tests were done on test pieces cut from the central section, the results of which are detailed in Table 6. The threshold stress values (also given as percentage of 0.2% PS) judged on micro-failure criteria can be seen to be:

alloy aged 12 hours, 22 MPa (5%);
alloy aged 20 hours, 33 MPa (7.5%);
alloy aged 72 hours, 32 MPa (7.5%);
alloy aged 144 hours, 65 MPa (17.5%);
alloy aged 240 hours, 101 MPa (25%).

5.5 Constant strain stress corrosion tests on DTD 5020A

Previous work at RAE[4,5], established macro- and micro-failure threshold stress values for stress corrosion cracking of alloy to DTD 5020A, using constant tensile strain tests on short transverse test pieces in both a marine atmosphere environment and by alternate immersion in 3.5% NaCl. The macro-failure threshold stresses obtained, (given also as percentage of 0.2% PS), were:

marine atmosphere 122 MPa (30%);
alternate immersion 104 MPa (25%).

The corresponding micro-failure threshold values were:

<104 MPa (<25%);
50 MPa (12.5%).

6 DISCUSSION

Threshold values for stress corrosion cracking in AU4SG obtained by tests in the two environments on unstretched alloy suggest that marine atmosphere exposure for 18 months is slightly more aggressive than alternate immersion in 3.5% NaCl for 30 days. This agrees with results obtained on other alloys[5].

Unstretched material aged to maximum strength is shown to be very susceptible to stress corrosion cracking, while the overaged material, although more resistant, is still very susceptible. No significant difference could be established in the resistance to stress corrosion cracking resulting from overageing at either temperature.

Comparing micro-failure threshold values for stretched alloy with values for unstretched alloy, exposed to the same conditions, revealed an improvement from 22 MPa to 33 MPa after ageing for 20 hours at 160°C, and from 50 MPa to 101 MPa after ageing at 160°C for 240 hours. However, when account is taken of the acceleration of the precipitation process (section 3), there is no real improvement in the stress corrosion behaviour when comparisons are made between alloys with

similar values of 0.2% PS. In any case, the results may have been affected by the higher quench rate experienced by the smaller blocks which were subsequently stretched.

Test environment probably accounts for the difference between ONERA and RAE results on the stress corrosion resistance of overaged AU4SG. This difference emphasises the caution which must be exercised in placing materials and heat treated conditions in an order of merit as a result of tests involving a single accelerated test environment, unless it has been clearly demonstrated that the test adequately relates to subsequent service experience.

7 CONCLUSIONS

(1) Constant tensile strain tests in both a marine atmosphere and by alternate immersion in 3.5% NaCl, and constant strain rate tests in 1 M NaCl showed that the 2014 type alloy, AU4SG, was very susceptible to stress corrosion cracking when aged to peak strength at both 160°C and 175°C.

(2) While overageing of the alloy at both 160°C and 175°C to cause a 10% reduction in its 0.2% PS improved the stress corrosion resistance, the overaged alloy was still susceptible to stress corrosion cracking, irrespective of the ageing temperature.

(3) Stretching the alloy after solution treatment did not improve the stress corrosion resistance of the alloy, either at peak strength or when overaged to cause a 10% reduction in the 0.2% PS.

(4) On the basis of constant tensile strain tests, 2014 type alloy produced to DTD 5020A was slightly more resistant to stress corrosion cracking than the overaged versions of AU4SG.

(5) Alternative immersion tests in 3.5% NaCl solution gave threshold stress values close to those obtained in natural marine tests, but markedly lower than those obtained in ONERA alternate immersion tests, either using 3% NaCl with the addition of phosphate and borate ions, or in 3% NaCl with the addition of dichromate ions.

(6) The results obtained indicate that with respect to stress corrosion resistance, there is no advantage in ageing AU4SG alloy at 160°C rather than at 175°C.

Acknowledgment

The use of the Exposure Trials Station, Eastney, of the Central Dockyard Laboratory is gratefully acknowledged.

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Table 1

CHEMICAL COMPOSITIONS OF ALLOYS IN WEIGHT PER CENT

Material	Cu	Si	Mg	Mn	Fe
2014 nominal	4.4	0.8	0.5	0.8	<0.7
DTD 5020A nominal	4.3	0.7	0.4	0.8	0.3
AU4SG actual	4.29	0.78	0.36	0.47	0.19
DTD 5020A actual[4]	4.28	0.73	0.38	0.74	0.29

Table 2

HEAT TREATMENTS OF AU4SG BLOCKS

Block	Solution treatment	Quenchant	Amount of stretch	Ageing conditions
A	6 hours at 510°C	Into water <20°C	None	20 hours at 160°C
B				240 hours at 160°C
C				8 hours at 175°C
D				48 hours at 175°C
4J21	6 hours at 510°C	Into water <20°C	Stretched, longitudinally, to give permanent deformation of 2.2 to 2.6%	12 hours at 160°C
4J22				20 hours at 160°C
4J24				72 hours at 160°C
4J25				144 hours at 160°C
4J26				240 hours at 160°C

Table 3

MECHANICAL PROPERTIES OF HEAT TREATED AU4SG, TESTED IN THE SHORT TRANSVERSE DIRECTION

Blocks, solution water quenched	treated 6 hours at 510°C, aged	0.1% PS (MPa)	0.2% PS (MPa)	0.5% PS (MPa)	TS (MPa)	'E' GPa	Elong: %
A	20 hours at 160°C	421	436.5	454.5	477.5	71	3.0
B	240 hours at 160°C	377	392	404.5	439	72	4.5
C	8 hours at 175°C	416.5	431.5	448	466.5	72.5	3.25
D	48 hours at 175°C	392	402	417	444	74	4.0
4J21 centre	12 hours at 160°C	409	431	455	474	73	4.0
end*		400	422.5	446.5	471.5	73	4.0
4J22 centre	20 hours at 160°C	405	431	452	476	72	2.5
end*		413	431.5	455	478	72	3.25
4J24 centre	72 hours at 160°C	383	397	412	448	74	4.0
end*		388.5	403	419.5	450	73	4.5
4J25 centre	144 hours at 160°C	360	374	392	440	73	4.0
end*		356	372	387.5	433	74	4.5
4J26 centre	240 hours at 160°C	364	380	397	428	74	4.0
end*		351.5	366	381.5	426	73.5	4.0

* Alloy at the ends of the blocks (see Fig 2), used for preliminary tests, would not have experienced the same amount of stretch as that at the centre.

Table 4

UNSTRETCHED AU4SG. SHORT TRANSVERSE TENSILE TEST PIECES EXPOSED UNDER CONSTANT STRAIN TO ALTERNATE IMMERSION IN 3.5% NaCl SOLUTION

Block	A			C			B			D		
ST and aged	20 hours at 160°C			8 hours at 175°C			240 hours at 160°C			48 hours at 175°C		
% of 0.2% PS	Stress MPa	Life days	L/ST section	Stress MPa	Life days	L/ST section	Stress MPa	Life days	L/ST section	Stress MPa	Life days	L/ST section
55	244	<1 f					244	30 ub	mf	226	30 ub	mf
35	157	<1 f		149	30 ub	mf	139	30 ub	mf	141	<30 f	
27.5	119	3 f		119	9 f							
25							98 98 98	30 ub 30 ub 30 ub	mf mf mub			
22.5	96	30 ub	mf				88 88	30 ub 30 ub	mub mf	91 91	30 ub 30 ub	mub mub
21.25	91	30 ub	mf	89 90	30 ub 30 ub	mf mf	84	30 ub	mub			
20	84	30 ub	mf				79 79	30 ub 30 ub	mf mf	81	30 ub	mf
17.5	73	2 f					68 68	30 ub 30 ub	mub mf	70 70	30 ub 30 ub	mf mub
15							59 59	30 ub 30 ub	mf mub	60 60	30 ub 30 ub	mf mf
13.75	62 62 61	30 ub 30 ub 30 ub	mf mf mf	60 59	30 ub 30 ub	mf mf	54 54	30 ub 30 ub	mf mub			
12.5							51 49	30 ub 30 ub	mub mub	50 50	30 ub 30 ub	mub mub
10.0	45 44 42	30 ub 30 ub 30 ub	mub mub mf	45 44 46	30 ub 30 ub 30 ub	mf mub mf				40	30 ub	mub
8.75	38 38 39	30 ub 30 ub 30 ub	mf mub mf	38	30 ub	mf						
7.5	33 32 33	30 ub 30 ub 30 ub	mf mf mub	32 32 32	30 ub 30 ub 30 ub	mf mf mf						
6.0	27 27	30 ub 30 ub	mf mf									
5.0	22 23	30 ub 30 ub	mub mub	21 21	30 ub 30 ub	mub mub						

f - failed before completion of exposure;

ub - unbroken at completion of exposure;

mf - failure detected on microscopic examination, at up to ×500 magnification, of a central, polished L/ST section;

mub - failure <u>not</u> detected on microscopic examination, at up to ×500 magnification, of a central, polished L/ST section.

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Table 5

UNSTRETCHED AU4SG. SHORT TRANSVERSE TENSILE TEST PIECES EXPOSED UNDER CONSTANT STRAIN TO A MARINE ATMOSPHERE

Block	A			C			B			D		
ST and aged	20 hours at 160°C			8 hours at 175°C			240 hours at 160°C			48 hours at 175°C		
	Stress MPa	Life weeks	L/ST section	Stress MPa	Life weeks	L/ST section	Stress MPa	Life weeks	L/ST section	Stress MPa	Life weeks	L/ST section
27.5							107.6	33 f				
							108.5	52 ub	mf			
							107.6	78 ub	mf			
22.5							88.3	52 ub	mf	90.8	52 ub	mf
							88.3	78 ub	mf	90.8	78 ub	mf
							88.3	78 ub	mf	90.8	78 ub	mf
17.5							68.2	52 ub	mf	70.1	52 ub	mf
							68.2	78 ub	mub	70.1	78 ub	mf
							68.2	78 ub	mf	78	78 ub	mf
15	66.3	16 f		64.8	33 f		58.6	52 ub	mf	61.2	52 ub	mf
	65.3	21 f		64.8	52 ub	mf	58.6	78 ub	mub	60.2	78 ub	mf
	65.3	78 ub	mf	64.8	78 ub	mf	60.5	78 ub	mf	61.2	78 ub	mf
12.5										50.3	52 ub	mf
										50.3	78 ub	mf
										50.3	78 ub	mub
10.0	43.6	23 f		43.5	52 ub	mf						
	44.5	52 ub	mf	43.5	78 ub	mf						
	44.5	78 ub	mf	43.5	78 ub	mf						
7.5	33.1	52 ub	mf	31.9	52 ub	mf						
	33.1	78 ub	mf	31.9	78 ub	mf						
	33.1	78 ub	mf	31.9	78 ub	mf						
5.0	21.8	33 f		22.2	52 ub	mf						
	21.8	52 ub	mf	21.3	78 ub	mf						
	21.8	78 ub	mub	23.2	78 ub	mub						

f - failed before completion of exposure;

ub - unbroken at completion of exposure;

mf - failure detected on microscopic examination, at up to ×500 magnification, of a central, polished L/ST section;

mub - failure not detected on microscopic examination, at up to ×500 magnification, of a polished, central, L/ST section.

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Table 6

STRETCHED AU4SG. SHORT TRANSVERSE TENSILE TEST PIECES EXPOSED UNDER CONSTANT STRAIN TO ALTERNATE IMMERSION IN 3.5% NaCl SOLUTION

Block	4J21			4J22			4J24			4J25			4J26		
ST, stretched and aged	12 hours at 160°C			20 hours at 160°C			72 hours at 160°C			144 hours at 160°C			240 hours at 160°C		
% of 0.2% PS	Stress MPa	Life days	L/ST section	Stress MPa	Life days	L/ST section	Stress MPa	Life days	L/ST section	Stress MPa	Life days	L/ST section	Stress MPa	Life days	L/ST section
35													130.3	30 ub	mf
													129.3	30 ub	mf
30													111.5	30 ub	mf
													110.5	30 ub	mub
25										93.5	30 ub	mf	100.7	30 ub	mub
										93.5	30 ub	mub	94.8	30 ub	mub
													94.8	30 ub	mub
20										75.9	30 ub	mub			
										74.0	30 ub	mf			
17.5										65.2	30 ub	mub			
15.0							59.2	30 ub	mf	56.5	30 ub	mub			
										55.5	30 ub	mub			
12.5	54.5	30 ub	mf	53.8	30 ub	mf	50.3	30 ub	mf						
	54.5	30 ub	mf				50.3	30 ub	mf						
10	45.8	30 ub	mf	43.2	30 ub	mf	43.4	30 ub	mf						
	44.8	30 ub	mub	43.2	30 ub	mub	40.5	30 ub	mf						
7.5	32.1	30 ub	mf	32.7	30 ub	mub	31.6	30 ub	mub						
				33.6	30 ub	mub	30.6	30 ub	mub						
6.0	25.3	30 ub	mf												
5.0	22.4	30 ub	mub												

ub - unbroken at completion of exposure;

mf - failure detected on microscopic examination, at up to ×500 magnification, of a central, polished L/ST section;

mub - failure not detected on microscopic examination, at up to ×500 magnification, of a central, polished L/ST section.

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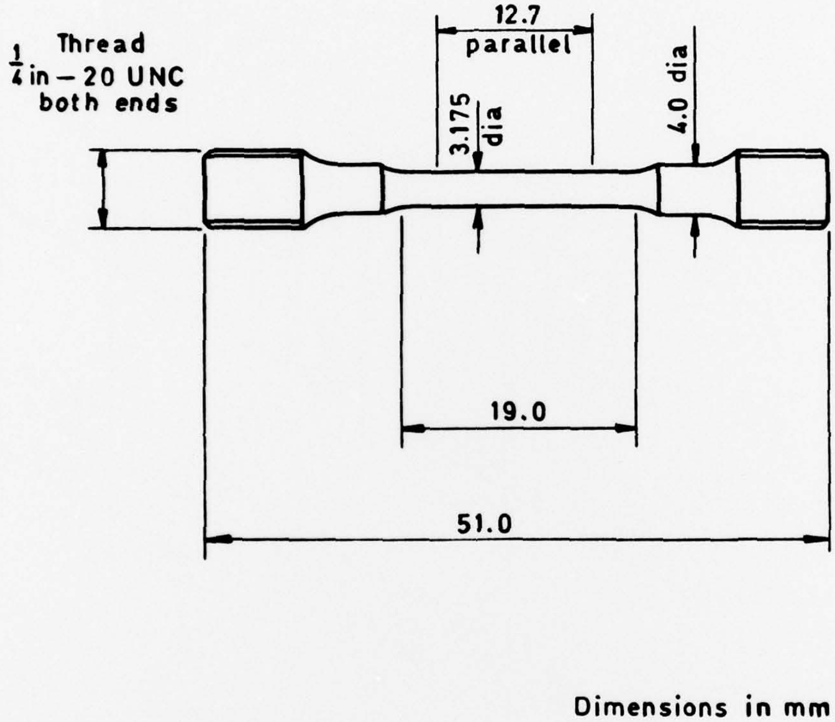


Fig 1 Test piece used for stress corrosion tests

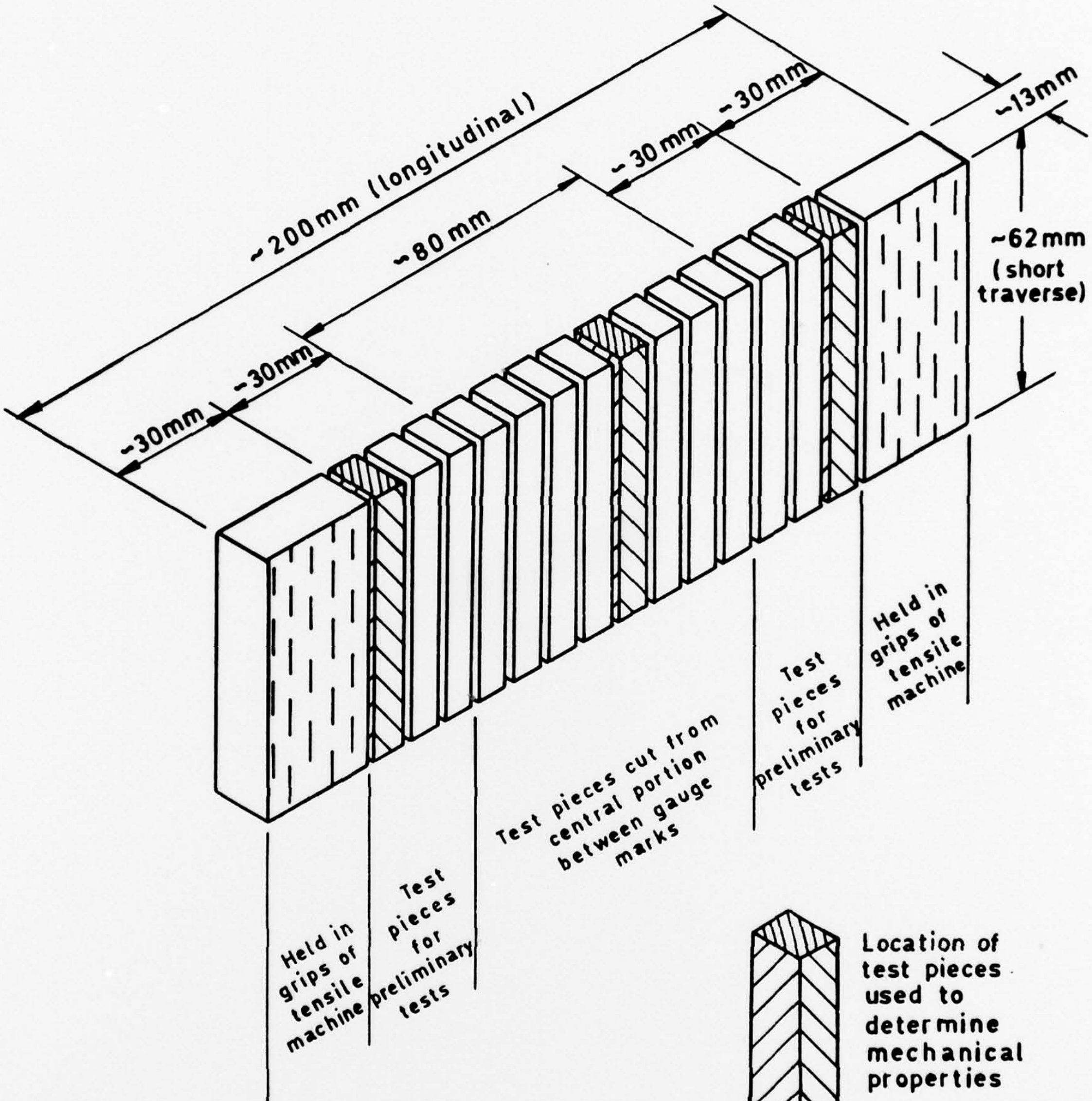


Fig 2 Location of test pieces cut from stretched plate

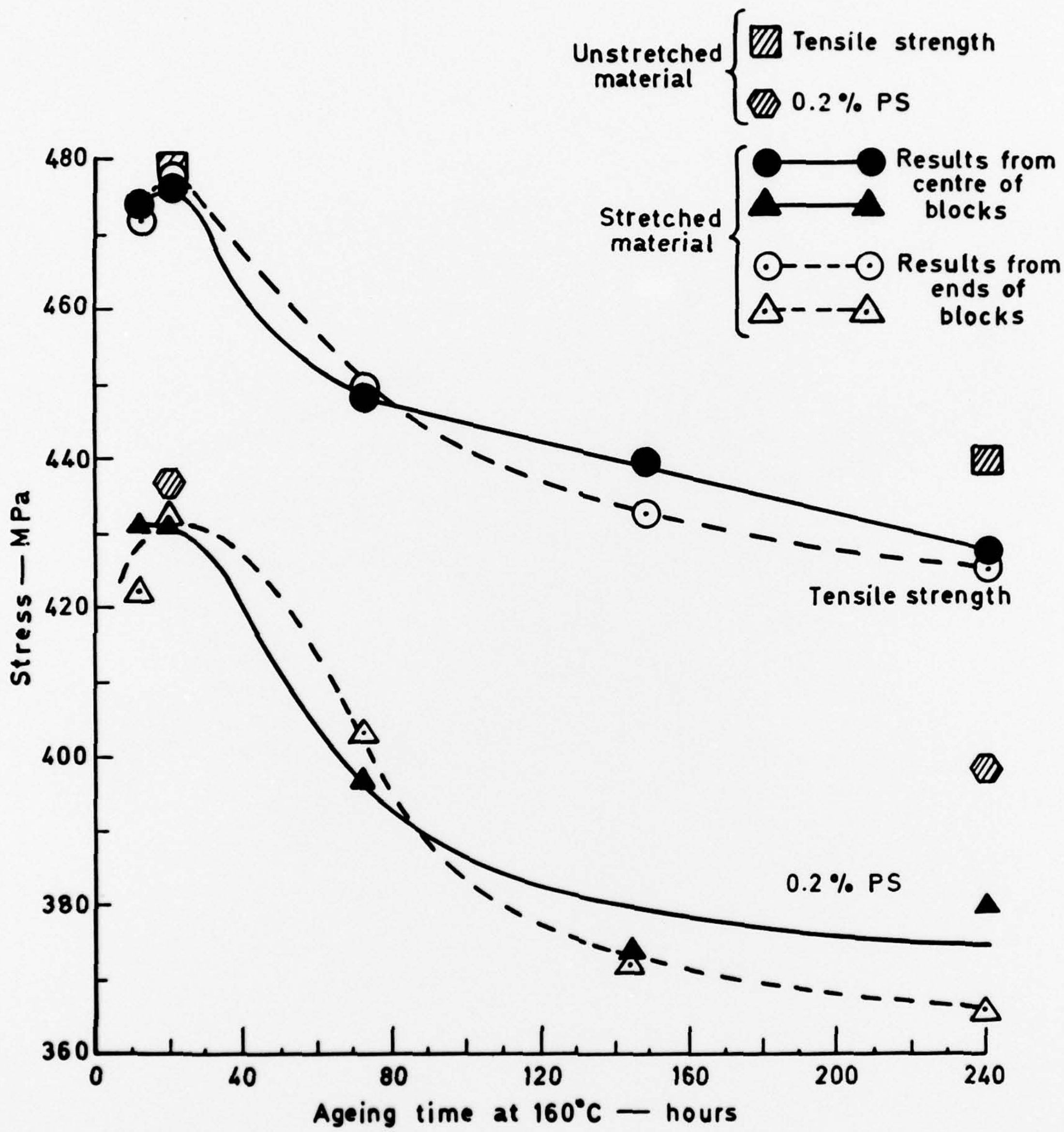


Fig 3 Effect of ageing time at 160°C on the tensile properties of stretched AU4SG

Fig 4

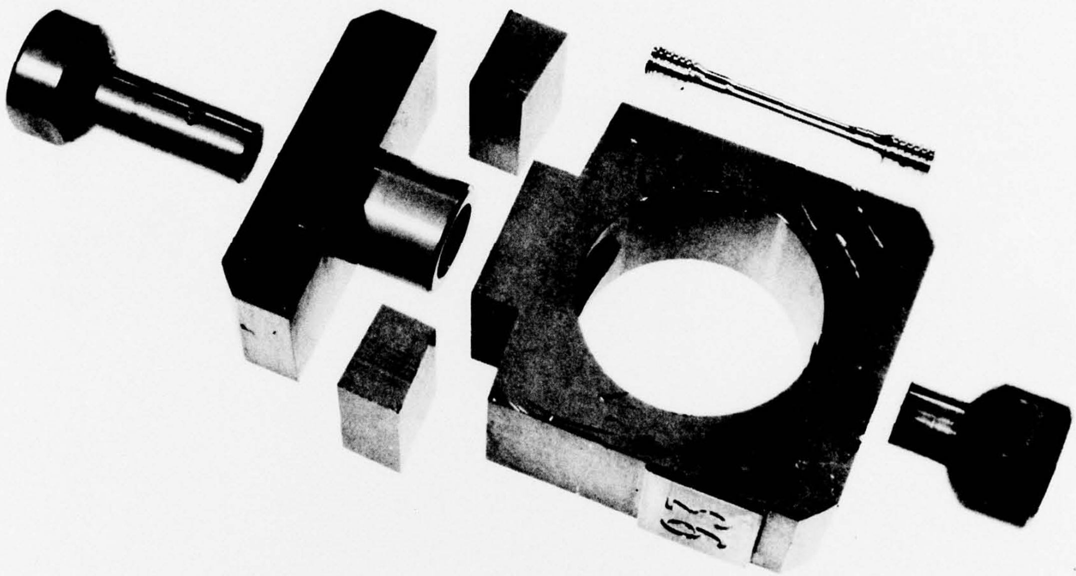


Fig 4 Exploded view of RAE one piece stress corrosion test rig and test piece

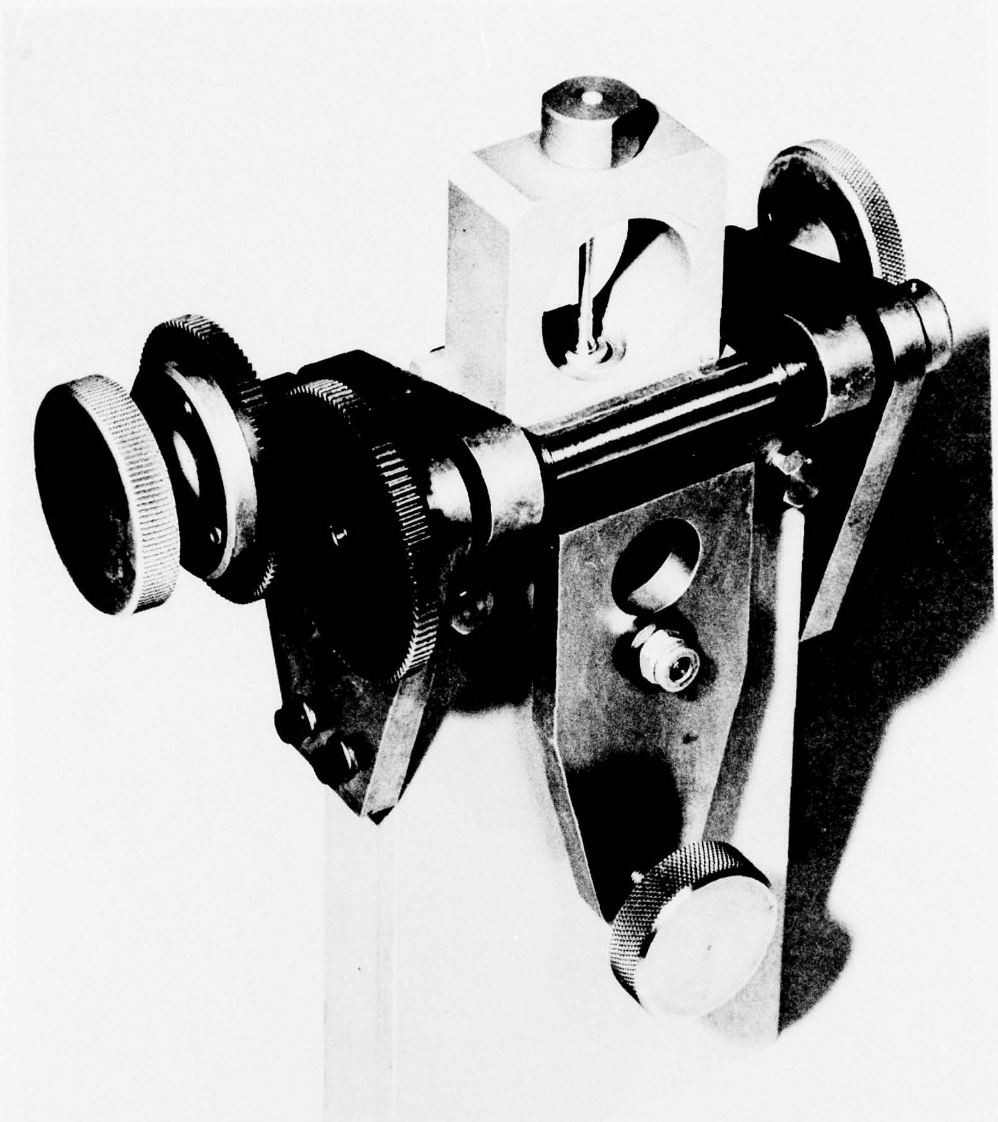
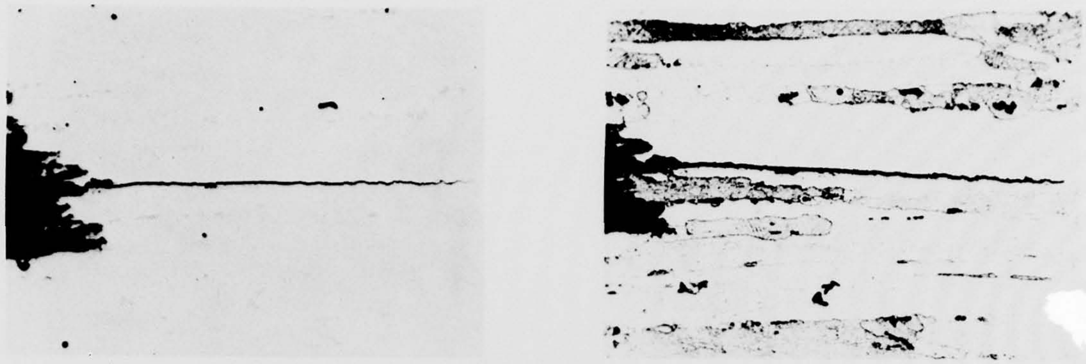


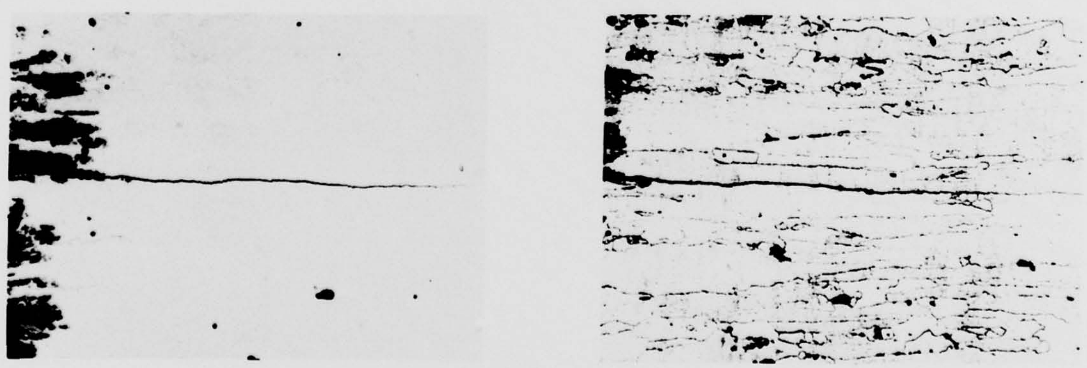
Fig 5 Wedge-driving device used to strain test pieces in RAE one piece stress corrosion rig



Etched Keller's reagent

Unstretched AU4SG, aged 20 h at 160°C
Stressed at 39 MPa, exposed for 30 days to alternate immersion in 3.5% NaCl solution

0.2 mm



Etched Keller's reagent

Unstretched AU4SG, aged 8 h at 175°C
Stressed at 90 MPa, exposed for 30 days to alternate immersion in 3.5% NaCl solution

Fig 6 Stress corrosion cracks detected microscopically in L/ST sections

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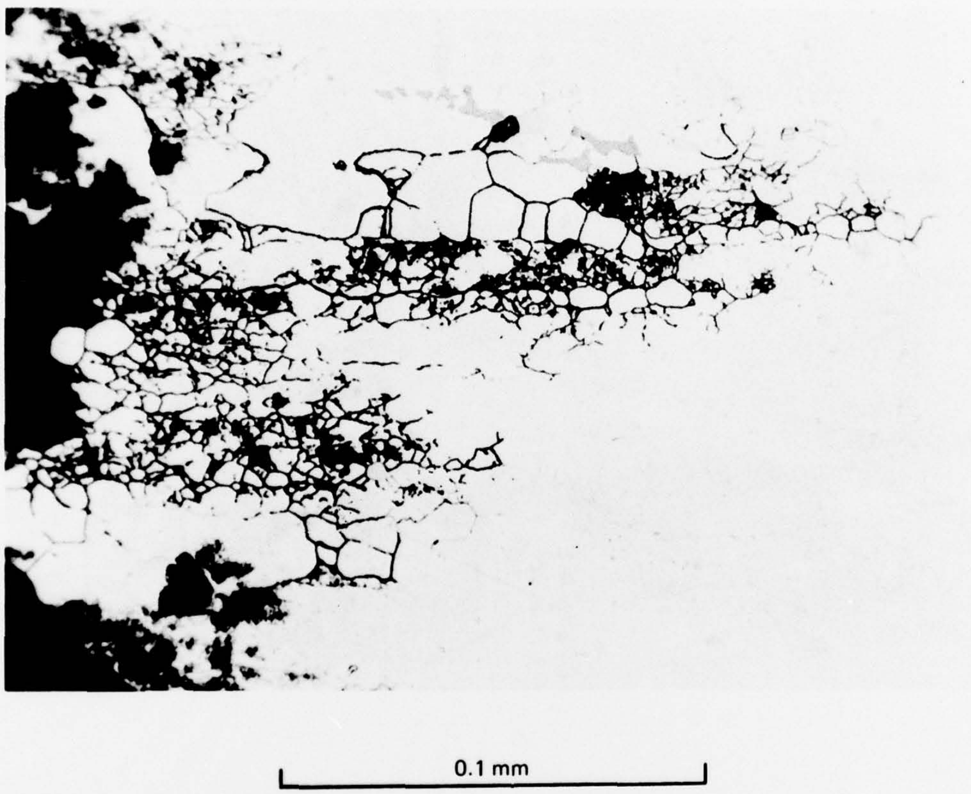

Unstretched AU4SG, aged 20 h at 160°C
Stressed at 23 MPa, exposed for 30 days to alternate immersion in 3.5% NaCl solution

Fig 7 Intergranular corrosion detected microscopically in L/ST section

REPORT DOCUMENTATION PAGE

Overall security classification of this page

UNCLASSIFIED

As far as possible this page should contain only unclassified information. If it is necessary to enter classified information, the box above must be marked to indicate the classification, e.g. Restricted, Confidential or Secret.

1. DRIC Reference (to be added by DRIC)	2. Originator's Reference	3. Agency Reference	4. Report Security Classification/Marking
	RAE TR 78054	N/A	UNCLASSIFIED

5. DRIC Code for Originator	6. Originator (Corporate Author) Name and Location
850100	Royal Aircraft Establishment, Farnborough, Hants, UK
5a. Sponsoring Agency's Code	**6a. Sponsoring Agency (Contract Authority) Name and Location**
N/A	N/A

7. Title

Stress corrosion testing of AU4SG aluminium alloy in plate form

7a. (For Translations) Title in Foreign Language

7b. (For Conference Papers) Title, Place and Date of Conference

8. Author 1. Surname, Initials	9a. Author 2	9b. Authors 3, 4	10. Date	Pages	Refs.
Gray, Josephine A.			May 1978	23	9

11. Contract Number	12. Period	13. Project	14. Other Reference Nos.
N/A	N/A		Mat 350

15. Distribution statement

(a) Controlled by – AD/XR Materials

(b) Special limitations (if any) –

16. Descriptors (Keywords) (Descriptors marked * are selected from TEST)

Stress corrosion*. Aluminium alloys*. Test methods*.

17. Abstract

The resistance to stress corrosion cracking in the short transverse direction of the 2014 type plate aluminium alloy AU4SG was assessed when aged to peak strength at either 160°C or 175°C, and when overaged. Stress corrosion tests were done in accelerated and natural environments using constant strain and constant strain rate techniques.

All of the tests demonstrated that AU4SG aged to peak strength was very susceptible, stress corrosion cracks occurring in the alloy stressed at less than 30 MPa. Overageing to the extent that a 10% loss in 0.2% proof stress resulted, slightly improved the alloy's resistance. Stretching the alloy after solution treatment accelerated the subsequent ageing process. No advantage was detected in the use of 160°C rather than 175°C for the ageing treatment. 2014 type alloy produced to DTD 5020A appeared to be slightly more resistant to stress corrosion cracking than the overaged AU4SG tested.

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